

CLAIMS

1       2. 1. A locating system for determining the location and  
2       3 orientation of an invasive medical instrument relative to a  
2       4 reference frame, comprising:

5       6       a plurality of field generators which generate known,  
5       6 distinguishable fields in response to drive signals;

7       8       a plurality of sensors situated in the invasive medical  
7       9 instrument proximate the distal end thereof which generate  
9        sensor signals in response to said fields; and

10      11      a signal processor which has an input for a plurality  
10      12      of signals corresponding to said drive signals and said  
10      13      sensor signals and which computes the three location  
10      14      coordinates and three orientation coordinates of a portion  
10      15      of the invasive medical instrument, responsive to said drive  
10      16      and sensor signals.

17      18      2. The locating system according to claim 1 wherein one of  
17      19      the plurality of field generators or sensors comprises three  
17      20      distinguishable, non-overlapping, generators or sensors.

21      22      3. The locating system of claim 1 wherein said plurality  
21      23      of field generators comprises three distinguishable, non-  
21      24      overlapping, generators and said plurality of sensors  
21      25      comprises three distinguishable, non-overlapping sensors.

26      27      4. The locating system of any of claims 1-3 wherein each  
26      28      sensor comprises a coil.

29      30      5. The locating system of claim 4 wherein said plurality  
29      31      of coils have axes which intersect within a coil.

32      33      6. The locating system of claim 4 or claim 5 wherein said  
32      34      plurality of coils comprises three coils and wherein said  
32      35      coils have axes which do not all intersect in a point.

36      7. The locating system of any of the preceding claims

1 wherein the fields generated by each of the field generators  
2 have a different frequency, a different phase, or both a  
3 different frequency and a different phase.

4

5 8. The locating system of any of the preceding claims,  
6 wherein the field generated by each field generator has a  
7 different frequency.

8

9 9. The locating system of claim 8, wherein the frequencies  
10 of the field generators are each integer multiples of a  
11 given frequency.

12

13 10. The locating system of any of claims 7-9, wherein the  
14 signal processor cross-correlates the signals corresponding  
15 to the drive and sensor signals.

16

17 11. The locating system of claim 9, wherein the signal  
18 processor cross-correlates the signals corresponding to the  
19 drive and sensor signals and wherein the duration of the  
20 cross-correlation of the inputs is the minimal common  
21 product of the integer multipliers divided by the given  
22 frequency.

23

24 12. The locating system of claim 10 or claim 11, wherein  
25 the results of the cross-correlation are used to calculate  
26 the contribution of each field generator to the signal  
27 generated by each said sensor.

28

29 13. The locating system of any of the preceding claims  
30 wherein the fields are AC magnetic fields.

31

32 14. The locating system of claim 13, wherein the AC  
33 magnetic fields are continuous fields.

34

35 15. The locating system of any of the preceding claims and  
36 including a display system for displaying the position of

1 the point on the invasive medical instrument.

2

3 16. The locating system of any of the preceding claims  
4 wherein there is an additional sensor on a portion of the  
5 invasive medical instrument which senses a local condition.

6

7 17. The locating system of claim 16 wherein the additional  
8 sensor senses local electrical signals and transfers them to  
9 terminals external to the patient's body.

10

11 18. The locating system of claim 17, wherein the signals are  
12 electrical signals from the endocardium of the patient's  
13 heart.

14

15 19. The locating system of claim 18, wherein the signal  
16 processor processes the position and orientation coordinate  
17 signals and the local electrical signals acquired at a  
18 plurality of points on the endocardium to generate a map  
19 that represents the propagation of electrical signals  
20 through tissue in the patient's body.

21

22 20. The locating system of any of claims 16-22 wherein the  
23 additional sensor is operative for supplying electrical  
24 energy to the endocardium for ablating a portion of the  
25 endocardium.

26

27 21. The locating system of any of claims 1-16 and including  
28 an electrode adapted for supplying electrical energy to the  
29 endocardium for ablating a portion of the endocardium.

30

31 22. The locating system of claim 16 wherein the additional  
32 sensor is an ultrasonic transmitter/receiver.

33

34 23. The locating system of claim 22 wherein the ultrasonic  
35 transmitter/receiver provides a less than three dimensional  
36 representation of the acoustic properties of tissue beyond

1 the distal end.

2

3 24. The locating system according to claim 23 wherein the  
4 distal end is deflectable.

5

6 25. The locating system according to claim 24 and including  
7 image reconstruction circuitry which receives a plurality of  
8 said less than three dimensional representations acquired at  
9 different orientations of the distal end and produces a  
10 three dimensional map of the acoustic properties of tissue  
11 at least partially surrounding the distal end.

12

13 26. The locating system of any of the preceding claims and  
14 further comprising a reference instrument which includes a  
15 plurality of sensors situated in the reference instrument,  
16 wherein said display system displays the position of the  
17 point on the invasive medical instrument relative to the  
18 position of a point on the reference instrument.

19

20 27. The locating system of claim 26, wherein the locating  
21 system comprises only a single reference instrument.

22

23 28. The locating system of claim 26 or claim 27 wherein the  
24 reference instrument is an invasive medical instrument and  
25 wherein said sensors are situated proximate the distal end  
26 thereof.

27

28 29. An imaging system for intra-body ultrasonic imaging  
29 comprising:

30 a invasive medical instrument having an axial-looking  
31 ultrasonic imaging transducer attached to a distal end of  
32 the instrument, which transducer generates a representation  
33 of the acoustic properties of tissue beyond the distal end;

34 means for manipulating the distal end to change the  
35 orientation thereof; and

36 image reconstruction circuitry which receives a

1       plurality of said representations acquired at different  
2       orientations of the distal end and produces a three  
3       dimensional map of the acoustic properties of tissue at  
4       least partially surrounding the distal end based on said  
5       plurality of representations acquired at different  
6       orientations of the distal end.

7

8       30. The imaging system of claim 29 and further comprising:

9            a plurality of field generators which generate known,  
10          distinguishable fields in response to drive signals;

11          a plurality of sensors situated in the invasive medical  
12          instrument proximate the distal end thereof which generate  
13          sensor signals in response to said fields; and

14          a signal processor which has an input for a plurality  
15          of signals corresponding to said drive signals and said  
16          sensor signals and which produces three location coordinates  
17          and three orientation coordinates of the a point on the  
18          transducer.

19

20       31. The imaging system of claim 29 or claim 30 wherein said  
21          representations are one or two dimensional representation.

22

23       32. The system of any of the preceding claims wherein the  
24          invasive medical instrument is a catheter or endoscope.

25

26       33. A method of determining the position and orientation of  
27          an invasive medical instrument having a distal end,  
28          comprising:

29            (a) generating a plurality of distinguishable,  
30          geometrically different AC magnetic fields;

31            (b) sensing the AC magnetic fields at a plurality of  
32          sensors proximate the distal end; and

33            (c) computing six dimensions of position and  
34          orientation of a portion of the invasive medical instrument  
35          responsive to signals representative of the generated  
36          magnetic fields and the sensed magnetic fields.

1  
2 34. A method according to claim 33 wherein the plurality of  
3 distinguishable, geometrically different fields comprises  
4 three such fields.

5  
6 35. A method according to claim 33 or claim 34 wherein the  
7 AC magnetic field is sensed at three points of the invasive  
8 medical instrument.

9  
10 36. A method according to any of claims 33-35 wherein the  
11 invasive medical instrument is a catheter or endoscope.

12  
13 37. An ultrasonic intra-body imaging method comprising:

14 (a) inserting an ultrasonic transducer into the body,  
15 said ultrasonic transducer producing a representation of the  
16 acoustic properties of tissue beyond an end of the  
17 transducer;

18 (b) manipulating the orientation of the transducer to  
19 provide a plurality of said representations;

20 (c) determining the six dimensions of position and  
21 orientation of the transducer for each of the  
22 representations; and

23 (d) constructing a three dimensional map of the  
24 acoustic properties of the tissue in a region at least  
25 partially surrounding the end of the transducer from said  
26 plurality of representations.

27

28 38. A method according to claim 37 wherein:

29 inserting a transducer comprises inserting an invasive  
30 medical instrument into the body of a patient, said  
31 ultrasonic transducer being positionally and orientationally  
32 fixed with respect to a distal end of the instrument; and

33 manipulating comprises changing the orientation of the  
34 distal end.

35

36 39. A method according to claim 37 wherein the

1 representation is a less than three dimensional  
2 representation.

3

4 40. A invasive medical instrument comprising a plurality of  
5 at least three magnetic field sensors proximate the distal  
6 end thereof, said sensors having a fixed orientation  
7 therebetween.

8

9 41. The instrument of claim 40 wherein each sensor  
10 comprises a coil.

11

12 42. The instrument of claim 41 wherein said plurality of  
13 coils have axes which intersect within a coil.

14

15 43. The instrument of any of claims 40-42 wherein the  
16 plurality is three.

17

18 44. The instrument of claim 41 or claim 42 wherein said  
19 plurality of coils comprises three coils and wherein said  
20 three coils have axes which do not all intersect in a point.

21

22 45. The instrument of any of claims 40-44 and further  
23 comprising an ultrasound transducer at said distal end.

24

25 46. The instrument of claim 45 wherein said ultrasound  
26 transducer provides a representation of the acoustic  
27 properties of tissue beyond and along the axis of the  
28 catheter.

29

30 47. The instrument of claim 46 wherein said representation  
31 is a one dimensional representation.

32

33 48. The instrument of claim 46 wherein said representation  
34 is a two dimensional representation.

35

36 49. The instrument of any of claims 40-44 and further

1 comprising an electrical probe at said distal end.

2

3 50. The instrument of claim 49 wherein said electrical  
4 probe is adapted to sense electrical signals generated by  
5 tissue which is in contact and conduct said signals to the  
6 proximal end of the catheter.

7

8 51. The instrument of claim 49 or claim 50 wherein said  
9 electrical probe is adapted to supply an ablative electrical  
10 signal to tissue contacting said probe.

11

12 52. The instrument of any of claims 40-44 and including a  
13 sensor for measuring local chemistry at the distal end.

14

15 53. The instrument of any of claims 40-52 wherein said  
16 instrument is a catheter or endoscope.

17

18 54. The instrument of any of claims 40-53 and also  
19 including means for changing the orientation of the distal  
20 end.

21

22 55. The instrument of claim 54 wherein the means for  
23 changing the orientation comprises:

24 a relatively more flexible wire passing through the  
25 medical instrument that is attached to the distal end and  
26 has a bend near the distal end;

27 a relatively more rigid sleeve which is straight near  
28 the distal end and which slideably holds the wire thereat,  
29 whereby when the sleeve is slid over the wire, the wire and  
30 distal end are straightened.

31

32 56. An instrument according to claim 55 wherein instrument  
33 has a lengthwise axis and wherein the wire is sited off the  
34 axis of the instrument.

35

36 57. An instrument according to claim 54 wherein the means

1 for changing the orientation comprises;  
2 a flat relatively flexible portion being slit along a  
3 portion of the length thereof to form two portions which are  
4 attached at a first end thereof, said first end being  
5 attached to the distal end of the instrument;

6 a pair of wires, one end of each of which being  
7 attached to one of said portions at a second end thereof;  
8 and

9 means for changing the relative lengths of the wires  
10 whereby the flexible element is bent, thereby steering the  
11 distal end of the instrument.

12

13 58. Apparatus for steering the distal end of an invasive  
14 medical instrument comprising:

15 a flat relatively flexible portion being slit along a  
16 portion of the length thereof to form two portions which are  
17 attached at a first end thereof, said first end being  
18 attached to the distal end of the instrument;

19 a pair of wires, one end of each of which being  
20 attached to one of said portions at a second end thereof;  
21 and

22 means for changing the relative lengths of the wires  
23 whereby the flexible element is bent, thereby steering the  
24 distal end of the instrument.

25

26 59. Apparatus according to claim 58 wherein the invasive  
27 medical instrument is a catheter or endoscope.

28

29 60. A method of producing a three dimensional image of the  
30 internal surface of an internal body organ comprising:

31 measuring the distance to said surface from a plurality  
32 of orientations and positions within the internal surface;  
33 and

34 assembling the distance measurements to form an image  
35 of the surface.

36

1 61. A method according to claim 60 wherein the measurement  
2 of distances is preformed utilizing an ultrasonic  
3 transducer.

4

5 62. A invasive medical instrument comprising a plurality of  
6 magnetic field sensors and an ultrasound transducer  
7 proximate the distal end thereof.

8

9 63. The instrument of claim 62 wherein said ultrasound  
10 transducer provides a representation of the acoustic  
11 properties of tissue beyond and along the axis of the  
12 catheter.

13

14 64. The instrument of claim 63 wherein said representation  
15 is a one dimensional representation.

16

17 65. The instrument of claim 63 wherein said representation  
18 is a two dimensional representation.

19

20 66. The instrument of any of claims 45-48 and 62-65 wherein  
21 the ultrasound transducer is positionally and  
22 orientationally fixed with respect to the distal end of the  
23 instrument.

24

25 67. The instrument of claim 66 and including means for  
26 controlably changing the orientation of the transducer by  
27 changing the orientation of the distal end of the  
28 instrument.

29

30 68. The instrument of any of claims 62-67 wherein said  
31 instrument is a catheter or endoscope.

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